**LAB EIGHT: NeuroProsthetics**

**OVERVIEW**

**In this lab you will:**

1. Learn about the characteristics of the nervous system that make neuroprosthetics a viable form of treatment for pathologies that interrupt the flow of neural information;
2. Observe the differences in scale between the magnitude of a recorded neural signal and the magnitude of stimulation that would be required to mimic that neural signal;
3. Test what effect a stimulation pattern that mimics a recorded biological signal from one limb can have on a second limb.

**OBJECTIVES**

**Before doing this lab you should:**

* review what happens in neural pathways during damage;
* study how electrodes interface with the nervous system during both recording and stimulating, and how the biological signal can be transduced (changed) to a form that a computer can use;
* learn about the current state of the art for brain-machine interfaces.

**After doing this lab you should be able to:**

* explain the difference between “biological” signal transmission and “machine” signal transmission;
* describe any differences in scale between the magnitude of the neural signals recorded and the required magnitude for a stimulation response, and why we might see those differences;
* design an experiment to test whether the recorded neural signal from moving one cockroach leg can be used as a stimulating signal to make a second leg move in the exact same way.

**EQUIPMENT**

* One SpikerBox
* Cockroach (two cockroach legs)
* Dissection scissors
* Toothpick or skewer that is broken in half so one end is pointy
* Two RadioShack Amplifier/speakers
* One Y-splitter
* Two “Patch” or laptop cables
* One stimulation cable

**INTRODUCTION**

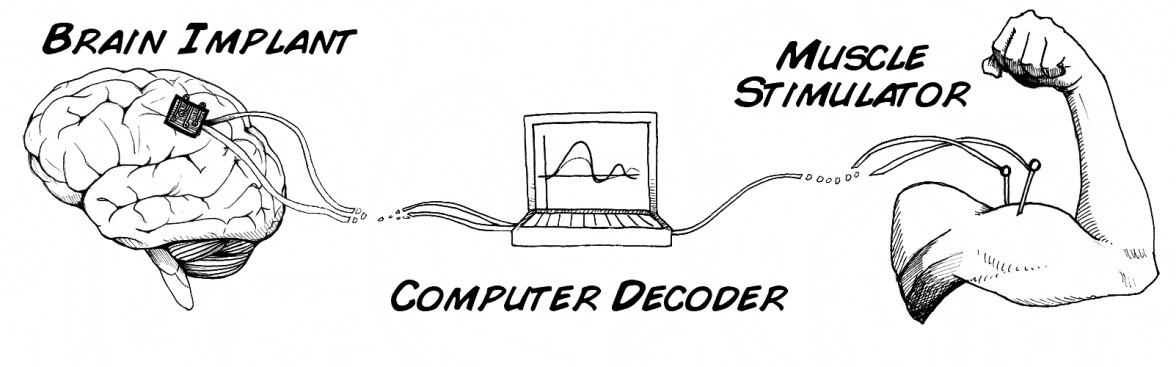
In experiment four we learned that our somatosensory system is a complex, multi-level network that includes receptors that interface with the outside world and generate an initial signal, nerves that carry that signal to the spinal cord, the cord that carries the information to the brain, and the brain that processes the info and decides what to do with it. This type of multi-level relationship is actually the basis of all of our senses, from vision (eyes to optic nerve to brain) to hearing (ears to auditory nerve to brain). The same is true for the opposite of sensing…Motor Control! Motor control also requires multiple levels of the nervous system working together to initiate movements. In the case of motor activity, though, the signal begins in the brain then travels down the spinal cord until it eventually reaches the muscles the brain wants to move. Thus, both healthy sensing and healthy motor function require an uninterrupted nervous connection between the brain and the peripheral input/output organs. And when that neural pathway is damaged, the resulting deficit is characterized by the loss of function…lack of vision is blindness, lack of hearing is deafness, and lack of ability to sense or control the legs is termed paraplesia (or paralysis), etc.

When a mammal breaks a bone, if the bone is set correctly it will often re-knit into a healthy bone. When a mammal tears a muscle, if given time to rest and recover the muscle will generally re-knit into an even stronger muscle (this is the foundation for weight training). However, in a continuing mystery to science, neurons in the mammalian brain and spinal cord do not regrow when damaged, save for the exception of a small population of neurons in the memory (hippocampus) and smell (olfactory) parts of the brain. Thus, given current technology, when damage occurs to the brain or spinal cord, sometimes engineers and doctors try to bypass the site of injury through electronic and computer means with devices called **neuroprosthetics**.

Mature “Hipster” neurons won’t regrow/divide when damaged.

Perhaps the easiest way to visualize a neuroprosthetic is to picture some famous storylines in science fiction movies or comic books. In “Empire Strikes Back”, Luke Skywalker had a robotic hand installed after Darth Vader cut it off, and Luke could control his hand simply by thinking about it. In “Star Trek, The Next Generation”, Giordi LaForge was a blind man that could see through a machine visor that interfaced with his brain. In the X-men movies, Professor Xavier had a huge machine, Cerebro, that interfaced with his brain through a helmet and enhanced his natural mental abilities.

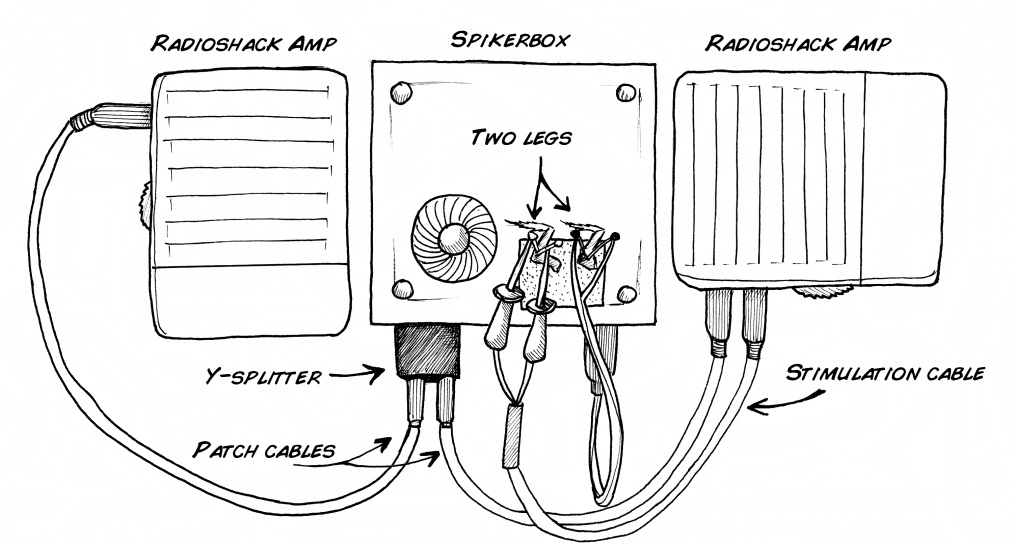
So, what do these examples all have in common? In each of them, a device interfaced with the nervous system to replace or enhance the function of a body part. This, then, is a working definition for a neuroprosthetic. And neuroprosthetics are no longer limited to science fiction…they have made their way into the real world. For example, if someone breaks their spinal cord above a certain point, they are confined to a wheelchair. But the muscles in their legs are still alive, and the brain can still initiate the command to move their legs. The message, however, cannot travel from the brain to the leg muscles because the spinal cord is damaged.



If there were a way to “read out” the command signal from the brain and use it to stimulate muscles or a robotic limb, such a device would be a neuroprosthetic. As we’ve seen in our experiments thus far, we can use electrodes to interact with the signals that are found in neurons. Action potentials are initiated and propagated through changes in cellular ionic concentrations, and the signal travels as charged ionic current. When an electrode is near a neuron, the charged ion currents induce electrons to move on the surface of the electrode that generates a similar magnitude current on the metal. And when the electrode is attached to a machine like your Spikerbox, the machine can then “read out” the neural signal. A [research group in Pittsburgh](http://motorlab.neurobio.pitt.edu/index.php) has used this exact neural recording technique to identify the command signals in a monkey brain that initiate movement, and then trained a monkey implanted with electrodes in his brain to control a robotic arm to feed itself. We will study a very basic neuroprosthetic preparation in this experiment.

**PROCEDURE**

**Exercise 1: Use the recorded neural signal from one cockroach leg to modulate the other**

1. Prepare cockroach legs as described in Experiment 1. Cut off two of the cockroach legs for use in this experiment.
2. Place the two cockroach legs on the cork of your SpikerBox, and hook up one leg to the SpikerBox in the standard way as in Experiment 1.
3. Plug the Y-splitter into the SpikerBox.
4. Plug the two patch cables into the Y-splitter.
5. Plug the two Radio Shack Amplifier/Speakers into the other ends of the two patch cables. One amplifier/speaker is for simultaneously listening to the spikes while doing your experiment, and the other amplifier/speaker is for stimulating the muscles of the second leg.
6. Plug the Stimulation Cable into one of the amplifiers
7. Place two needles into the second cockroach leg, and hook up the stimulation cable to these two needles
8. Turn on one of the amplifier/speakers to hear the spikes, and then turn on the second amplifier (the “stimulating” amplifier).
9. After the brief initial movement in the stimulated leg (due to capacitive discharge when the amplifier is turned on), slowly turn up the volume on the stimulating amplifier until the leg starts twitching. Then, turn the volume down below this point (bringing the leg just “below threshold”).
10. Begin brushing the leg that is hooked up to the SpikerBox.
11. Make note of any changes in the leg that you brush (the “recorded” leg)
12. Make note of any effects that you note on the “stimulated” leg when you brush the “recorded leg”

**DISCUSSION QUESTIONS**

1. In this experiment, we plugged two secondary amplifiers into the SpikerBox. One amplifier was simply to allow us to hear the spikes and is not that important. However, the second amplifier was needed to amplify to spikes to a high enough (approximately 2 volts) voltage to stimulate the second leg. What does this say about the difference between the size of the neural signals that we are recording, and the size of the stimulation signal required to effect a change in the leg? What is the explanation for this difference?

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1. From previous experiments, we learned that neural signals travel through the nervous system using action potentials (spikes). What are the charge carriers that generate action potentials in the body called (hint: Na+, K+, Cl- are examples of these)? When current travels through electrodes and computers, the charge carrier is different. What is the name of the charge carriers for electricity? Since the charge carriers are different, how do electrodes interface with the body? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. In this experiment, what effect did brushing the “recorded” leg have on that leg? What effect did brushing the “recorded” leg have upon the “stimulated” leg? How would you design an experiment to test whether the recorded neural signal from manually moving one cockroach leg could be used to make a second leg move in the exact same way? Based on the results of the present experiment, do you believe that the proposed/hypothetical experiment would work perfectly in a human? Why? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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